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Translocation of captive-bred dibblers *Parantechinus apicalis* (Marsupialia: Dasyuridae) to Escape Island, Western Australia

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Abstract

The introduction of threatened marsupials to islands affords a high degree of translocation success due to the lack of exotic species on islands, or the feasibility of eradicating them. The dibbler *Parantechinus apicalis* is a small marsupial endemic to the southwest of Australia. It is listed under international and national legislation as Endangered, and has been the focus of a successful conservation strategy to introduce captive-bred individuals to an island as a security measure, and as part of a formal Interim Recovery Plan. A total of 88 individuals were released in four groups on Escape Island from 1998 to 2000. The population was monitored using radiotelemetry and trapping techniques from 1998 to 2001. Breeding and dispersal of young occurred within the first year of release. Three years after the initial release, the third generation of wild-born dibblers had entered into the population. The total cost of this translocation exercise approximated $AUS 0.6 million. The conservation effort to give additional security to dibblers has been successful, at least in the short term, due to the collaboration between four organisations and a commitment to support a monitoring program of the released population over time.

Keywords: Island; Marsupial; Translocation; Conservation introduction; Captive breeding

1. Introduction

The management of threatened species by translocation is an important strategy used in the conservation of species across Australia. Translocation, whether a reintroduction, or an introduction for conservation purposes, is one tool available for the recovery of species whose populations face recognised and immediate, yet difficult-to-manage, threatening processes. On mainland Australia, wildlife translocations have had varying success (Short et al., 1992; Fischer and Lindenmayer, 2000; Short and Turner, 2000). Islands, on the other hand, have afforded an important environment to translocate threatened species both in Australia and overseas (Danks, 1995; Thomas and Whitaker, 1995; Abbott, 2000; Morris, 2000; Oehler et al., 2001). The value of Australian islands for fauna conservation and recovery is of high significance, and in particular, for mammals (Burbidge, 1999; Abbott, 2000). For example, 43 islands support 29 taxa of Australian threatened mammals (Abbott and Burbidge, 1995).

Predation by the introduced red fox *Vulpes vulpes* and the feral cat *Felis catus* are two major causes for the decline or extinction of Australian mammals (Kinnear et al., 1988; Burbidge and McKenzie, 1989; Short and Smith, 1994). The control of these predators has seen an immediate increase in the abundance and diversity of fauna across several areas in Western Australia (Kinnear et al., 1988; Short and Turner, 2000; Morris, 2000). However, where predator control has not occurred, or where it has been difficult to achieve, predation continues to hamper the re-establishment of many species (Christensen and Burrows, 1995; Gibson et al., 1994). To circumvent the immediate risks associated with the management of threatened populations that occur in sympatry with exotic predators, several populations have been introduced to islands in what have been defined as conservation introductions (IUCN, 1998), and where the eradication of exotic mammals has been successful (Burbidge, 1999).

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The introduction of threatened taxa to islands for conservation purposes affords a higher degree of success than translocations to mainland sites due to the lack of exotic species, or the feasibility of eradicating them (Moro, 1997; Risbey et al., 1997; Algar, 2000; Langford and Burbidge, 2001). There are various goals of conservation introductions, including the expansion of the current range of a species, the increase of populations to avoid genetic problems associated with small size, or the establishment of satellite populations to reduce the loss of single species populations resulting from environmental catastrophes (Komdeur, 1994; Abbott, 2000; Morris, 2000; Langford and Burbidge, 2001). Offshore islands are being increasingly used as an environment that can protect native species from threats on the mainland. These conservation introductions are not a haphazard action by conservation agencies to delay the management of threats causing these declines. Rather, they must satisfy rigid external assessments before they may proceed, and are critical to the survival of diminishing populations of native fauna (see Serena, 1995).

The dibbler *Parantechinus apicalis* is a small marsupial (40–80 g) endemic to southwestern Australia. Given the rarity of recent records on mainland Australia, and the small size of island populations, the dibbler was listed as Endangered under Australian Commonwealth (Environment Protection and Biodiversity Conservation Act 1999) and international (IUCN) legislation. It was subsequently the focus of a state-wide conservation and management plan (Start, 1998a).

This paper describes the (1) introduction of dibblers to Escape Island, Western Australia, (2) population dynamics and demographics of the founder population, and (3) subsequent successful establishment of the surviving progeny. An estimation of the costs of the introduction is also reported to describe the commitment required to translocate species to islands.

2. Study site and species

Escape Island lies 200 km north of Perth, and approximately 3 km offshore from the town of Jurien (30°18′S, 115°02′E), Western Australia (Fig. 1). The island is gazetted as a nature reserve. It is smaller in area (10.5 ha) then Boullanger Island (26 ha), but larger than Whitlock Island (5.4 ha). Escape Island has extensive areas of limestone with areas of deep, calcareous sands. The region has a Mediterranean climate characterised by cool wet winters and hot dry summers. Mean maximum temperatures of 26 °C occur in January and February and mean minimum temperatures of 12 °C occur during July. Average rainfall is approximately 750 mm of which 60% falls between June and August. A seasonal drought occurs during the summer months from November to March. Vegetation comprises structurally-dense and diverse thickets of the shrubs *Scaveola crassifolia*, *Rhagodia baccata, Acacia rostellifera, Olearia axilaris*, and *Acanthocarpus preisii*.

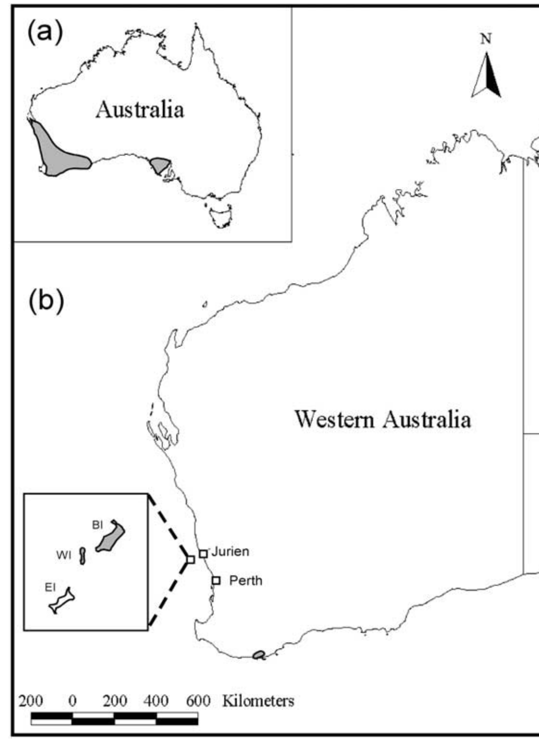

Fig. 1. Location map showing distribution of the dibbler. Boullanger Island (BI), Whitlock Island (WI) and Escape Island (EI). (a) Past distribution prior to European settlement, (b) present distribution.

The dibbler is a dasyurid marsupial that had a known distribution across a large section of the southwest of Western Australia, including parts of South Australia, prior to European settlement (Fig. 1a). Prior to the late 1960s, the last specimen was collected in 1904 (Fisher, 1998). This species was thought to be extinct until 1967, when an individual was captured in the southwest of Western Australia (Morcombe, 1967). In 1985, dibblers were also discovered on two small islands (Boullanger Island, Whitlock Island) off Western Australia (Fuller and Burbidge, 1987). Its current distribution represents a decline of some 90% of its former range (Fig. 1b). The reasons for their decline on the mainland remain unknown, although is likely to be equivalent to that recorded for other native mammals: predation from introduced predators such as feral cats and foxes, land clearing, altered fire regimes, and local vegetation extirpation following fungal disease spread by *Phytophthora* (Woolley, 1980; Short and Smith, 1994; Short, 1998; Start, 1998a).

Dibblers are crepuscular in habit, though activity has been recorded during daytime hours. Their diet consists predominantly of invertebrates, though some plant (berry) material is consumed when available (Bencini et al., 2001; Miller et al., in press). Mating occurs during

March or April, and a female may carry up to eight young in a shallow pouch. Dispersal of young occurs during September and October. A post-mating male die-off was reported in three consecutive years from island dibblers (Dickman and Braithwaite, 1992), but recent evidence suggests this does not occur in all years (Mills and Bencini, 2000).

3. Methods

The recovery of the dibbler in Western Australia followed a structured decision-making process. An Interim Recovery Plan (Start, 1998a) was developed by a formally constituted Recovery Team comprising members from government agencies, universities and the community. In accordance with government policy, the Interim Recovery Plan was formally endorsed by the Western Australian Director of Nature Conservation within the State Department of Conservation and Land Management. One of the criteria identified for success of the recovery of the dibbler in Australia was that a new island population be established by the introduction of captive-bred individuals (Start, 1998a). Under the direction of the Interim Recovery Plan, a decision was made to introduce island dibblers to a secure area.

In accordance with actions in the Interim Recovery Plan, and with State government policy, a Translocation Proposal was prepared by the Recovery Team, and subjected to an independent referee process prior to its formal endorsement by the Director of Nature Conservation (Start, 1998b). The Translocation Proposal incorporated specific steps for implementation of the introduction. These were (1) breed dibblers in captivity for release, (2) justification for an introduction, (3) selection of a suitable release site, (4) criteria established for success or failure of the introduction, (5) transfer and release of animals, and (6) post-release population monitoring.

3.1. Captive breeding colony

Dibblers were reared in captivity from four pairs of wild animals collected from Boullanger and Whitlock Islands. The total numbers of offspring reared are given in Table 1. With the exception of five individuals, all dibblers released were the result of a successful captive breeding program at Perth Zoo (Bradley et al., 1999). Husbandry details will be reported elsewhere (Lambert, unpublished data).

3.2. Justification for an introduction

One of the immediate elements for the recovery of the dibbler was to ensure the future security of the two island populations. Boullanger and Whitlock Islands currently experience dramatic fluctuations in densities of house mice *Mus domesticus*. These add an unknown risk to dibblers with respect to competition for food and space, and risks associated with disease transmission during high densities of house mice (Dickman, 1992). In addition, both islands are easily accessible from the nearby townsite of Jurien. This increases the risks associated with fire, weeds, or the possible introduction of exotic predators. The introduction aimed to create a third island population that was free from disturbances associated with house mice and people, and could act as an insurance against some catastrophe befalling the other two island populations.

Table 1
Numbers of dibblers born in captivity, and released to Escape Island

Year	Born				Raised successfully		
	Male	Female	Unknown	Total	Male	Female	Total
1997	4	15	2	21	4	15	19
1998	12	13	23	48	12	13	25
1999	20	22	10	52	20	22	42
2000	1	2	2	5	1	2	3
2001	0	0	0	0	0	0	0
Total	37	52	37	126	37	52	89

Introductions to islands require careful consideration due to the intrinsic conservation value of islands relative to mainland environments. It was considered that there were no other significant and intrinsic conservation values that might be compromised by the presence of dibblers (Start, 1998a). There were strong conservation reasons for the decision to undertake a conservation introduction. Translocation to mainland areas was not considered to be an appropriate management action, as suitable reintroduction areas had not been identified. It was considered imprudent to use island dibblers as reintroduction stock to south coast sites for health and genetic reasons, and due to the local adaptation of individuals to an island environment. Consequently, introduction to an island was considered the least risky option available to manage the island populations (Start, 1998a).

3.3. Choice of destination

Escape Island lies almost 1 km from Whitlock Island, and was assessed as a suitable release site for dibblers (T. Start, A. Burbidge, P. Fuller, in litt.). The island is currently free from exotic predators and rodents, and shows strong vegetation similarities with the islands where the founder dibblers survive. There are no terrestrial mammals. However, a large breeding population of burrowing seabirds occurs across the island. Seabird colonies have survived with dibblers on Boullanger and Whitlock Islands, so dibblers are unlikely to threaten them. Escape Island is also difficult to land on, dissuading visitation by people visiting the island and

reducing risks associated with fire and the introduction of weeds and pests.

3.4. Criteria for success and failure

It was considered important to have defined and measurable criteria that could identify whether the introduction to the island (and subsequent population establishment) would be considered successful. These criteria were identified because it was particularly pertinent to state the aims and the time scale of the introduction outcome (Fischer and Lindenmayer, 2000).

The population would be deemed successful, and the population would be considered to be established on Escape Island, in the short-term (less than 5 years), if individuals within the free-ranging population produced second generation young that survive to breed and produce viable, dispersing offspring. Long-term establishment and success would be assumed if the population size sustained itself and approximated known-to-be-alive numbers similar to those recorded for Boullanger Island or Whitlock Island during the same year of sampling. Conversely, the introduction would be described as unsuccessful if the population did not survive beyond 2 years, or if there was no reported recruitment into the population during any breeding season up to 5 years of the initial release. These criteria are strict, but set a precedent towards the careful active adaptive management (sensu Walters and Hilborn, 1978) of translocated species.

3.5. Preparation and release phase

All dibblers were implanted with Trovan PIT tags under the skin at the base of their necks for identification. The animals were given health checks by veterinary staff at Perth Zoo a few days prior to the translocation. Dibblers were fed twice their usual daily food supply two days prior to their release. On the day of their release, they were transferred to individual wooden nest boxes with sterilised leaf litter, transported 300 km by vehicle to the town of Jurien, and then 4 km by boat onto Escape Island, where they were released at four locations in the northern section of the island at dusk. Nest boxes were left open at the sites for 5 days after release, and removed unless there was evidence animals were using them.

3.6. Post-release monitoring phase

Approximately one-third of released dibblers were fitted with single-stage radiotransmitters (Biotrack) attached to flexible rubber collars around their necks. Transmitters were fitted under anaesthesia to reduce handling-related stress while animals were still at the zoo, and. The total transmitter weight did not exceed 2–4% of the total body mass. Following release, 25 dibblers (eight in 1998, 17 in 1999) were radiotracked and their day locations recorded during the first 2 weeks. One day after release, the day locations of all collared dibblers were recorded to identify location, dispersal, and incidences of mortality. After the 2-week battery life of the transmitters, collars were removed from trapped individuals.

Subsequent monitoring involved trapping. Up to 100 Elliott aluminium folding traps (320×900×1000 mm) were spaced at approximately 20-m intervals. Traps were set in three rows that extended the entire length of Escape Island. This ensured that the majority of the island was sampled. Trapping occurred over three to four nights at key times of year. Dibblers were monitored pre- and post-breeding season (February–April), and pre- and post-dispersal season (September–November).

Captured individuals were weighed, identified, sexed, and their reproductive condition noted. Subadult animals were defined by the time of year of capture (October–December); animals captured between January and September were defined as adult. Females were recorded as reproductive if they had pouch young, were lactating, or showed obvious signs of distended teats. The scrotal area (width×length) of males was measured with callipers as an indication of testes size across the year. Body condition was scored on a four-tiered scale by the same investigator: poor (body emaciated, hair loss, animal appears sickly), okay (some hair loss, generally thin in appearance), good (animal appears active, no signs of hair loss, tail and body appears healthy), or very good (no hair loss, animal very active, fatty base to tail, animal appears healthy). New individuals had a Trovan PIT tag implanted under the skin at the base of their necks for future identification. Pouches were checked for young or lactating teats and when present, the numbers counted. Faecal samples were collected to identify gut parasites acquired since release, and all animals were released at the site of capture.

Demographic parameters are reported as means and standard deviations. Population size was reported as the minimum number of animals known to be alive (Krebs, 1966) each trip. Body mass was compared using Student's *t*-tests after data were logarithmically transformed. Chi-square analysis was used to test sex ratios for adults against the assumption of parity. Survivorship of each founder group and each generation of young born on Escape Island was estimated based on trap records over time.

4. Results

4.1. Founder groups

There were no mortalities of dibblers during their movement from the enclosures of Perth Zoo to the

release site. A total of 88 individuals was released in four groups to Escape Island from 1998 to 2000 (Tables 1 and 2). Founder dibblers comprised 33 adult and 55 subadult individuals (Tables 1 and 2). The second release was staggered to allow a second group of individuals (mostly females) to increase sufficiently in body mass prior to their release. Two dibblers were released in 2001 to clear up the zoo enclosures for the housing of mainland dibblers. All four releases represented 'hard' releases where animals were not acclimatised to the release site and where no supplementary food was provided.

Table 2
Age, sex structure, and body mass at the time of release, of founder dibblers introduced to Escape Island. Body mass values represent mean (±SD). Two individuals (1 male: 1 female) from the 2000 progeny born at the zoo were released in June 2001

Year	Sex	Age	*n*	Body mass at release g
1998	F	Subadult	6	37.8 (2.5)
		Adult	11	53.4 (6.1)
	M	Subadult	7	52.4 (5.4)
		Adult	2	62 (14.1)
Total			26[a]	
1999	F	Subadult	15	34.9 (2.8)
		Adult	9	56.7 (4.5)
	M	Subadult	13	46.6 (3.2)
		Adult	4	66.0 (6.3)
Total			41[b]	
2000	F	Subadult	7	45.4 (3.2)
		Adult	2	64.5 (0.7)
	M	Subadult	7	67.3 (8.5)
		Adult	3	63.7 (10.2)
Total			19[c]	
2001	F	Adult	1	58.0
	M	Adult	1	72.0
Total			2[d]	

[a] 1998 release consisted of 24 zoo-born (2M:9F from 1997 and 7M:6F from 1998) + 2 (0M:2F) founders.

[b] 1999 releases consisted of 40 zoo-born (0M:4F from 1997, 4M:4F from 1998 and 13M:15F from 1999) + 1 (1M:0F) founder.

[c] 2000 release consisted of 17 zoo-born (1M:2F from 1999 and 7M:7F from 2000) + 2 (2M:0F) founders.

[d] 2001 release consisted of 2 zoo-born (1M:1F from 2000).

4.2. Dispersal and survivorship of founders following release

Individuals were released in several areas in the north of the island. Resting locations changed daily for all individuals. With the exception of two individuals, all remained within 400 m of their release site (range 50–800 m) 3 weeks after release. Two individuals stayed within 50 m of their release site for 1 week, then moved elsewhere on the island where they remained subsequently. Day refugia comprised dense vegetation of *Scaevola crassifolia* and *Acacia rostellifera*.

Two mortalities were recorded during each October release. All four individuals were subadults born during their year of release. There were no signs of predation, so the cause of death remains speculative. Post-mortem analysis of two individuals identified an empty stomach consistent with signs of starvation.

4.3. Population size

Dibblers exhibited some degree of shyness to capture since not all individuals were trapped at any one time. Trap success increased with time to 19.4% in October 2000, dropped during May and June 2001, and increased to 17.7% in October 2001 (Fig. 2). High captures in October 2000 and 2001 coincided with the period of juvenile dispersal. Following the initial 2-week release, the minimum number of dibblers known to be alive was reported each trip from 1998 to 2001 (Fig. 3). Numbers known to be alive peaked in 2000 at 131 individuals, of which 91 individuals were young born on the island. The following year, numbers known to be alive dropped to 67, but there was no further supplementation of founders to the population. Of these 67 individuals, 63 (representing 94% of the dibblers known to be alive in 2001) were born on Escape Island. Compared with known to be alive estimates for Boullanger Island and Whitlock Island (Fig. 3, H. Mills, K. Wolfe and A. Stewart, unpublished data), known to be alive values on Escape Island are higher for the period 1999–2001, and indicate that Escape Island is suitable for the survival of dibblers in the short term.

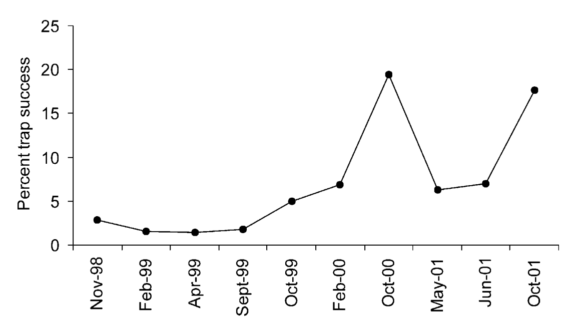

Fig. 2. Success (expressed as a percentage trap success) of trapping dibblers on Escape Island, 1998–2001.

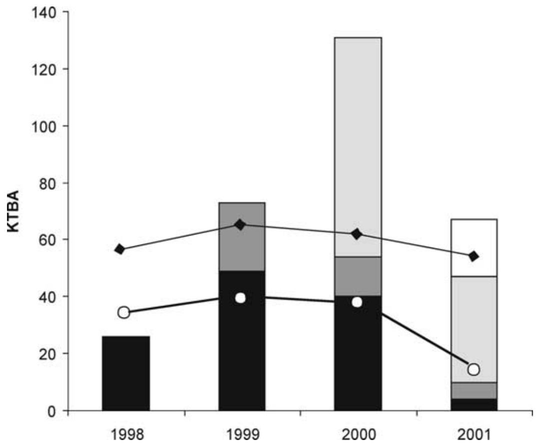

Fig. 3. Number of dibblers known-to-be-alive on Escape Island from 1998 to 2001. Shaded bars, founder dibblers; hatched bars, first generation young; dotted bars, second generation young, open bars, third generation young. Comparative average numbers known to be alive for Boullanger Island (open circles) and Whitlock Island (diamonds) are represented as lines (Mills et al., unpublished data).

4.4. Body mass

With the exception of June 2001, when females were carrying young in the pouch, adult male dibblers were significantly heavier (overall mean body mass 61±5.1 g) than females (49.6±4.7 g, $t=3.33$, $P=0.004$, Fig. 4). Subadult males (40.7±6.7 g) and females (35.9±5.1 g) were of similar body mass. Adult females consistently dropped in body mass just prior to, during, or just after the mating season of March–April. Adult males were lighter during October 1999 and June 2001.

4.5. Sex ratio

The overall sex ratio of dibblers was skewed towards females, with an average ratio of 0.76:1 male:female (Table 3). This overall ratio was a significant departure from an expected 1:1 sex ratio ($\chi^2=4.44$, $P=0.038$). When age cohorts were separated, only during 1999 was there a significant bias in captures towards adult females ($\chi^2=3.86$, $P=0.045$); sex ratios did not significantly depart from an expected 1:1 at any other time of year, and the sex ratio for both adults and for subadults was close to parity.

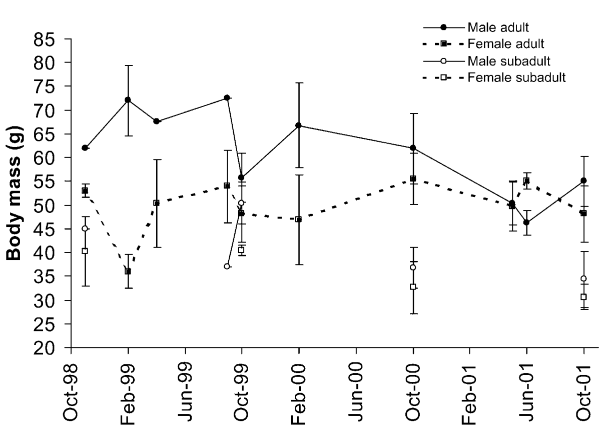

Fig. 4. Variation of body mass of dibblers trapped on Escape Island 1998–2001. Values represent mean and standard deviation.

4.6. Longevity

Founder females are known to have lived significantly ($t=3.04$, $P=0.004$), longer (minimum average age of 23±4.4 months, range 10–30, $n=51$) than founder males (17±2.5 months, range 11–19, $n=37$). The minimum average age for first generation females born on Escape Island was 13.5±2.8 months (range 10–18 months), but did not significantly differ to the age of first generation males of 16±2.1 (range 14–18) months.

4.7. Survivorship of founders

Of the 26 dibblers released in 1998, 39% survived two months after release, and 16% survived to 24 months after their release (Fig. 5). Survivorship of founders released in October 1999 was higher, with 93% of individuals surviving in the population 10 months after their release. Numbers dropped to 32% at 12 months post release, remained steady for another 6 months, then dropped to 2.5% at 26 months after their initial release. The release of dibblers in January 2000 coincided with high immediate losses two months after release, with survivorship dropping to 16%. These losses were only just below those recorded for animals released in 1998. Nevertheless, surviving individuals from the third release remained in the population up to 24 months.

4.8. Breeding and reproduction

Dibblers bred during March–April each year since their release in 1998. Young appeared in the pouch during May, and were deposited in nests during the mid-year months from June to August. Dispersal of young into the population was recorded as early as September, though captures were highest in October.

The percentage of females showing signs of enlarged pouches, recent lactation, or pouch young increased almost nine-fold, from 20% in 1999 to 90% in 2001 (Fig. 6). Average body mass for females known to have bred was 54±7.4 g (range 40–67.5 g, $n=52$). All females were in good or very good body condition. The number of young in the pouch averaged 7±1.1 (range 3–8, $n=35$ litters).

Adult males occurred in the population across and between years. Changes in the scrotal area of adults were seasonal, with maxima being reached prior to the breeding season in late summer, and falling after the autumn breeding period (Fig. 7).

Table 3
Age and sex demographics of dibblers captured on Escape Island 1999–2001

	Adult			Subadult		
	Male	Female	Total	Male	Female	Total
1999	6	15	21	17	22	39
2000	19	25	44	28	26	54
2001	21	32	53	15	19	34

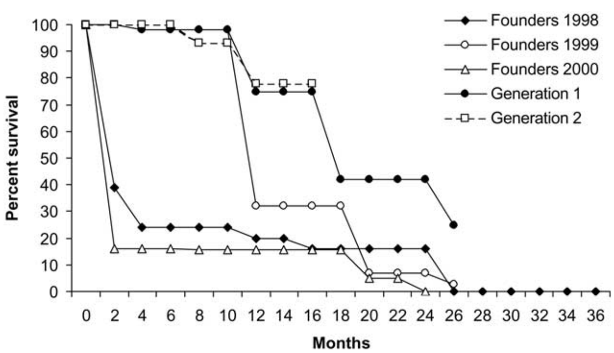

Fig. 5. Dibbler survivorship on Escape Island with time, expressed as a percentage of original total individuals known-to-be-alive.

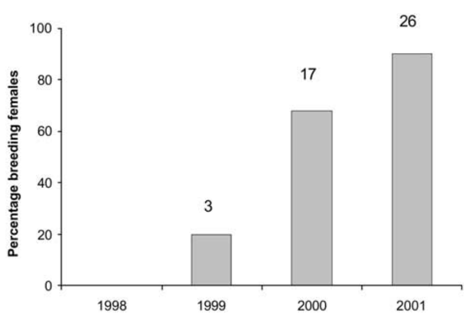

Fig. 6. Percentage of female dibblers known-to-be-alive and showing evidence of breeding. Sample sizes are shown above bars.

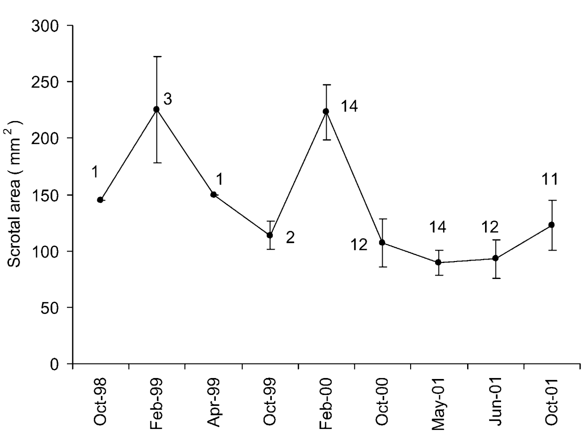

Fig. 7. Change in mean (±SD) scrotal area (length×width) of male dibblers on Escape Island, 1998–2001. Numbers represent sample sizes.

4.9. Recruitment and survivorship of young

A minimum of 121 dibblers was born on Escape Island from 1999 to 2001. The minimum number of individuals increased from 24 (nine male: 15 female) in 1999 (Generation-1) to 77 (35 male: 41 female) in 2000 (Generation-2). The minimum number of individuals born on Escape Island in 2001 (Generation-3) was 20 (8 male: 12 female), though this fig. is an under-representation given that future trapping effort is likely to capture more individuals representing Generation-3. For example, only 10 dibblers comprising Generation-1 were captured in 1999, and an additional 14 of the 1999 progeny were captured in 2000. Likewise, of 77 individuals captured from Generation-2, 40 were trapped in 2000 and 37 in 2001.

Overall survivorship was higher for individuals born on Escape Island (Fig. 5). Of 24 first generation young produced from founders released in 1998, 98% survived to 10 months, and 25% persisted in the population 26 months after initial capture. Similar survivorship occurred for the second generation of young born on Escape Island, with survivorship falling slightly to 78% eight months after initial captures of these young, and to 78% at 16 months (Fig. 5).

4.10. Body condition

Overall body condition for dibblers varied from okay (6.6% of captured individuals), to good (59.4%) to very good (34%). There was a significant departure from expected in the body condition of male and female dibblers ($\chi^2 = 6.58$, $P = 0.04$). There were more males and fewer females than expected whose body conditions were described as okay or very good. However, fewer males and more females than expected had a body condition described as good. When comparisons are made between sexes for (founder) dibblers introduced to Escape Island, body condition did not significantly differ from expected between the sexes ($\chi^2 = 0.99$, $P = 0.61$). In contrast, there were significant differences between the sexes for body condition of dibblers born on Escape Island ($\chi^2 = 14.6$, $P = 0.001$); there were more males and fewer females than expected whose body conditions were defined as okay and good, but fewer males and more females than expected with a very good body condition.

5. Discussion

This research presents information on the use of a conservation introduction as a management strategy for a threatened mammal in Australia. Dibblers have established on Escape Island following the survival of a third generation of wild-born progeny. At least in the short-term, the introduction has been successful.

The establishment of dibblers to Escape Island is consistent with past introductions of native fauna to islands for conservation reasons (Burbidge, 1999; Morris, 2000; Moro, 2001). Of 10 translocations (representing 9 taxa) to islands that have been approved in Western Australia, 80% were introductions, and of these, 88% have been described as successful (Table 4). Success is often attributed to a lack of predators (Abbott, 2000). The reintroduction of Banded Hare-wallaby to Dirk Hartog Island was due to feral cats, and there has been some degree of predation by native varanids on Shark Bay mice *Pseudomys fieldi* introduced to North West Island (Morris, 2000).

The population of dibblers on Escape Island has survived since 1998, and known to be alive estimates for 2001 are higher than those currently known from either Boullanger Island or Whitlock Island (Mills and Bencini, 2000). Monitoring showed that there was no post-mating male die-off on Escape Island, and concurred with results for Boullanger Island and Whitlock Island during the same years, although there was evidence that male die-off may be facultative on Boullanger Island (Mills and Bencini, 2000). On Escape Island, males were becoming reproductively active in late summer, as shown with the substantial increase in scrotal area (Fig. 7). A similar trend was reported in the other two island populations (Mills and Bencini, 2000). Increased scrotal size has been associated in other species with elevated levels of circulating testosterone and with the onset of spermatogenesis (Wolf et al., 2000).

Attributing success to a translocation should not be defined as an end result, and perspective should be used in revisiting the outcome. Applying the criteria that define introduction as success or failure, the introduction of dibblers to Escape Island has been successful in the short term because a second generation of wild-born dibblers bred to produce dispersing offspring. On-going monitoring of the population in the next few years will compare population levels to those of Boullanger Island and Whitlock Island, and will determine whether the long-term success of the introduction is warranted. The long-term success of a translocation has no guarantee; the initial survival of a population of the giant land tortoise *Geochelone gigantea* translocated to the Seychelles was only short-term following the decline of the population one decade later (Hambler, 1994). Post priori recognition of a translocation as successful is important so that conservation effort can be reduced and focused elsewhere, and ongoing costs minimised. If the current introduction had not met the criteria for success then future management should have redirected finances and effort.

The number of released individuals comprising a founder population is an important criterion for the

Table 4
Translocation of native fauna to islands in Western Australia for the purpose of conservation

Common name	Species	Translocation type	Source	Destination	Result[a]	Source
Mammals						
Banded Hare-wallaby	*Lagostrophus fasciatus*	Reintroduction	Dorre Is.	Dirk Hartog Is.	N	[b]
Burrowing Bettong	*Bettongia lesueur*	Reintroduction	Barrow Is.	Boodie Is.	Y	
Dibbler	*Pseudantechinus apicalis*	Introduction	Captive colony + wild stock, Boullanger & Whitlock Islands	Escape Is.	Y	[c]
Greater Stick-nest Rat	*Leporillus conditor*	Introduction	Captive colony (Monarto Zoo)	Salutation Is.	Y	[g]
Lakeland Downs Short-tailed Mouse	*Legaddina lakedownensis*	Introduction	Thevenard Is.	Serrurier Is.	Y	[d]
Rothschilds Rock-wallaby	*Petrogale Rothschildi*	Introduction	Enderby Is.	West Lewis Is.	Y	[b]
Rufous Hare-wallaby	*Lagorchestes hirsutus*	Introduction	Tanami Desert	Trimouille Is.	Y	[e]
Shark Bay Mouse	*Pseudomys fieldi*	Introduction	Bernier Is.	Doole Is.	Y	[g]
		Introduction	Captive progeny from Bernier Is. stock	North West Is.	N	[g]
Birds						
Noisy Scrub Bird	*Atrichornis clamosus*	Introduction	Mt Gardner, Two Peoples Bay Nature Reserve	Bald Is.	Y	[f]

[a] Translocation successful (Y) or unsuccessful (N).
[b] Short et al., 1992.
[c] This study.
[d] Moro, 2001.
[e] Langford and Burbidge, 2001.
[f] Danks, 1997.
[g] Morris, 2000.

establishment of the founder group (Fischer and Lindenmayer, 2000). Large founder numbers will increase the genetic representation of the population, and may circumvent problems associated with genetic erosion (Wolf et al., 1996; Leberg, 1999). A review of animal translocations by Fischer and Lindenmayer (2000) suggests that the release of approximately 100 individuals will increase the success of a translocation rather than the release of fewer individuals. The supplementation of further individuals into the translocated population may indeed have been the critical factor that promoted the survivorship and breeding of dibblers on Escape Island by providing a core local population, despite high mortality of individuals following the first release in 1998. There was a clear increase in the recruited population of dibblers into the population in 2000 following the release of 41 individuals in 1999. A high mortality of a third founder group released in early 2000 suggests that this group is unlikely to have contributed significantly to the status quo of the population. An annual supplementation of dibblers into the existing population may have boosted the population above the minimum threshold it required to persist against demographic, genetic and environmental perturbations.

A knowledge of the genetic composition of a founder population prior to its translocation remains an under-represented component of translocation exercises (see Serena, 1995), although many programs consider that the genetic diversity of a founder group may be maximised by increasing founder size (Leberg, 1999). Fragmented populations are susceptible to stochastic difficulties such as inbreeding depression, loss of genetic variation, and mutational compression. Some island populations exhibit naturally low levels of genetic variability (Frankham, 1997; Moro et al., 1998; Eldridge et al., 1999), and these populations may persist because deleterious alleles have been purged (Brakefield and Sacceri, 1994). The genetic variability of dibblers from Boullanger Island and Whitlock Island is low relative to those in the southwest of Western Australia (Mills, unpublished data). It is unlikely that low genetic representation on Escape Island will be detrimental to the population's future persistence unless there has been further genetic erosion due to a limited breeding pool following the mortality of some of the original founders (Frankham, 1997). Information on the genetic variation of the Escape Island population warrants research to identify just how much variation exists. Future conservation measures may require that 'new blood' from the original two island populations is necessary to increase the effective population size on Escape Island to a level that allows a species to maintain its evolutionary potential (Franklin and Frankham, 1998).

There are two important outcomes from this translocation project: husbandry improvements for future translocations of small marsupial species, and a sense of pride which has developed from a close collaboration between several organisations prepared to commit the resources to the long-term conservation of a species. The captive breeding programme was the first to successfully breed dibblers (Bradley et al., 1999). Dedicated full-time zoo keepers, husbandry protocols that were progressively altered to closely replicate the dietary and housing conditions of the natural environment (Lambert, unpublished data), together with reproductive information gained from scientists that identified the best time to pair males with females (Bradley et al., 1999), led to an adaptive management approach to optimise breeding success of captive individuals, and the success of the breeding program to produce sufficient young for release each year. In addition, a multi-faceted team (listed in the acknowledgments) approach to the recovery of this species has led to the success of this conservation project. The knowledge related to the procedures, time, and field techniques gained from the recovery of dibblers to Escape Island can now be transferred to efforts to re-establish additional populations along the south coast of Western Australia following recent fox-baiting exercises.

The results from the introduction of dibblers to Escape Island are encouraging. However, to categorise the current introduction as successful in the short term should not imply that the future monitoring of this population is no longer warranted. Future monitoring of the dynamics and demographics of all three island populations must continue at least once per year for 5 years, and comparisons made to detect any fluxes in numbers over time. The genetic composition of the Escape Island population should also be addressed in case future augmentation of this population with wild stock is necessary to increase genetic representation. It is only with this properly planned and coordinated vision of adaptive management, together with the skills of experienced people and the commitment of funding, that these research programs can be implemented and become recognised as projects that provide the proof-of-concept that some species can indeed be recovered from extinction.

5.1. Costs of introduction

The expenses incurred with translocation events are rarely reported (Fischer and Lindenmayer, 2000), yet these are valuable to gauge the future commitment that is required to undertake a wildlife translocation event. Costs represent an estimate of conservation commitment required to undertake the introduction of dibblers to Escape Island, and to subsequently monitor the population three years after the initial release (Table 5). These costs have been obtained from Perth Zoo (unpublished data). Husbandry costs include salaries for keepers, veterinary staff, the director of research, and

Table 5
Estimates of costs associated with the captive breeding and field monitoring of dibblers to Escape Island from 1998–2001

Activity	Estimated costs ($AUS×1000)				Total
	1998	1999	2000	2001	
Captive breeding					
Husbandry per individual	6.1	4.2	11.7	0	
Total released	26	41	19	2	88
Total	158.6	172.2	222.3	0	553.1
Field release and monitoring					
Transport to/from island	1.1	1.5	1.5	1.1	5.2
Monitoring	4.3	10.0	6.2	5.8	26.3
Total	5.4	11.5	7.7	6.9	31.5
Total cost	164.0	183.7	230.0	6.9	584.6
Total costs per individual released	6.3	4.5	12.1	3.5	6.6

research assistants. Also included are costs associated with equipment for animal housing, diet supplies, and all zoo overhead costs. Using these figs. as an estimate, and applying it to the total number of dibblers bred in captivity, an approximate budget of $AUS 6300 was needed to breed for release each individual dibbler to Escape Island from 1998 to 2001, and a minimum of $AUS 6,600 per individual to conduct the introduction program (Table 5). Costs related to vessel transfers to and from the island were met through in-kind support from local fishing groups. Total expenses approximate just over $AUS 0.5 million to conduct the dibbler introduction program from 1998 to 2001. These figures represent a clear investment of money to the recovery of an endangered species.

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